BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B69 08003

SUBJECT: Characteristics of the Ten Lunar Exploration Sites - Case 340

DATE: August 1, 1969

FROM: F. El-Baz

ABSTRACT

The ten lunar exploration sites recommended by the GLEP Site Selection Subgroup have been approved by the ASSB on July 10, 1969 as a working set of sites. These include:

A. Two landings in mare materials
   Site 2 in old, Imbrian ("eastern") mare
   Site 5 in young, Eratosthenian ("western") mare

B. Two landings in regional stratigraphic units
   Blanket deposits of the Fra Mauro Formation
   The Sulpicius Gallus Formation at Rima Bode II

C. Three landings near or within impact craters
   The northwestern ejecta rim of crater Censorinus
   The north rim of crater Tycho (Surveyor VII site)
   The central peaks of crater Copernicus

D. Constructional features of probable volcanic origin
   Domes and cones in the maria; Marius Hills
   Volcanic features in the highlands; Descartes

E. A sinuous rille
   Rima Prinz I

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MEMORANDUM FOR FILE

INTRODUCTION

It is most important at this time to plan for the Apollo missions which will follow the first lunar landing by (1) selecting the sites and their alternates, (2) assigning a mission sequence, and (3) commencing the necessary site analyses and mapping.

Provided that there are 10 missions in the first phase of manned lunar exploration, a set of sites should include:

1. The two types of mare material, "eastern" or Imbrian (older) and "western" or Eratosthenian (younger)

2. Regional stratigraphic units such as blanket (ejecta) deposits around mare basins

3. Various types and sizes of impact craters in maria and in highlands

4. Morphological manifestations of volcanism in maria and in highlands

5. Areas which may give clues to the nature and extent of processes, other than impact and volcanism, which may have acted upon the lunar surface.

These requirements meet both the geological and geochemical objectives of the aforementioned phase of lunar exploration. The geophysical objectives require a specific mission assignment plan particularly for the construction of seismic networks. Other scientific objectives do not call for much that would contradict this rationalization.

With these considerations in mind, and as a first step in planning for Apollo 11 to Apollo 20, a set of sites is proposed (Figure 1). Investigation of these sites would best meet the scientific requirements and achieve the objectives of lunar exploration. The mission assignments were based largely on the geophysical requirements, i.e., the construction of geophysical networks (Figure 2).

DESCRIPTION OF THE SITES

Following are brief descriptions of the ten sites which were recommended by the GLEP Site Selection Subgroup and tentatively accepted by the ASSB on July 10, 1969 as a working set.

1. Landing Site 2 (eastern mare)

This site is located entirely within relatively old (Imbrian) mare material. There are many large subdued craters 200-600 m in diameter; the number of intermediate size craters 50-200 m in diameter is fewer than on younger mare material in other sites. This crater distribution is common on many apparently old surfaces including the Imbrian blanket (Fra Mauro Formation). It may reflect a thicker layer of surficial debris in these areas of relatively old terrain so that intermediate size craters have an initially soft appearance and are rapidly destroyed. An alternative explanation is that a mantle of pyroclastics is present; some craters near the site may be volcanic and could be the source of the pyroclastics. Determination of the age and nature of mare material (Imbrian) is the prime object of a landing in this site; determination of whether or not pyroclastics are present will have application to many other areas with similar crater populations.

2. Landing Site 5 (western mare)*

This site is located within relatively young (Eratosthenian) mare material. In contrast to Landing site 2, the area of this site displays a large number of intermediate size craters 50-200m in diameter and a small number of larger subdued craters 200-600m in diameter. The site is surrounded by well-developed ray clusters of the Kepler system. Small, weakly-developed crater clusters and lineaments radial to Kepler occur within the site. Thus some material derived from depth at Kepler may be present in the surficial material and fine-scale textural details related to the Kepler rays may also be present. There are more resolvable blocks (> 2m) around craters than in the three sites to the east (Landing sites 1, 2 and 3) suggesting that the surficial material is generally coarser grained. The

*The geology of both landing site 4 (near a Tycho ray) and landing site 6 (the Flamsteed P ring) is comparable to that of site 5 and hence both sites are considered alternates to site 5.

chief goal of a landing in the site is determination of the age and composition of the Eratosthenian mare material.

3. Fra Mauro Formation

The site of the Fra Mauro Formation is in an extensive geologic unit covering great portions of the lunar surface around Mare Imbrium. Therefore a mission to this site would result in an understanding of the nature, composition, and origin of this widespread formation. The latter is interpreted as ejecta from Imbrium. An alternative to the Fra Mauro Formation, although in somewhat different terrain (the Cayley Formation), would be Hipparchus.

4. Censorinus

Censorinus is a 3.8 km probable impact crater located within, but near the edge, of a highland block south-southeast of Mare Tranquillitatis. The proposed landing site is to the north of the crater within the ejecta blanket and about 1 km from the rim. The site offers a unique opportunity to sample, early in the lunar exploration plan, both highland material and features associated with a fresh impact crater. Censorinus is large enough to exhibit clear signs of impact, but small enough to be investigated on a foot traverse. If operational constraints indicate the impossibility of landing on the Censorinus ejecta blanket, the site of Littrow (where a fresh wrinkle ridge meets the Serenitatis Bench and both are covered by dark mantling material) may be considered for the fourth landing.

5. Rima Bode II

Rima Bode II is a single linear rille which runs close to a fresh, elongate crater and a crater chain. Both the rille and the crater are possible sources of a number of dark geologic units most probably of volcanic origin. Therefore, the site was selected as an example of a volcanic region where it would be expected to sample deep seated

material. The alternative to this site in Hyginus which displays very similar characteristics, but is less fresh-appearing. The aforementioned site of Littrow would meet part (sampling of the Sulpicius Gallus Formation) of the objectives of a mission to Rima Bode II.

6. Tycho (rim)

Tycho is also a fresh impact crater, in the southern highlands. However, it is much larger than Censorinus (about 85 km in diameter) and thus offers an opportunity of studying the many features common to large, fresh impact events, including associated volcanism. The vicinity of the landing site of Surveyor VII is the proposed landing site. In that area one encounters several generations of flows, a pond or pool, ejected blocks (probably from Tycho), other ejecta features and structures, and last but not least the Surveyor VII spacecraft.

7. Copernicus (peak)

The crater Copernicus is a bright rayed crater, up to 95 km in diameter, whose visible radial rays spread out distances of several hundred kilometers. The walls of the crater Copernicus expose a vertical section of about 4 km of the lunar crust. The floor, 60 km in diameter, is nearly circular, and contains a small, almost central, multiple peak, with large masses to the east and the west, where the highest peak rises 800 meters. These peaks may have brought to the surface material that once lay at considerable depth. A mission to the central peaks would be mainly a sampling mission, with some emphasis on structural relationships. Samples of large blocks on the peaks, of the floor material, and of the mounds on the floor would be of significance to the geochemistry of the moon.

8. Marius Hills

The Marius Hills are domes and cones near the center of Oceanus Procellarum, and west-northwest of the crater Marius, where isolated hills and clusters of hills rise above the mare surface and form part of a major north-south median ridge system that stretches irregularly for some 1900 km through Oceanus Procellarum. Many of the hills exhibit the convex upward shapes suggestive of terrestrial laccolithic instrusions; and some

resemble terrestrial shield volcanos. The variety of these features and their similarity to terrestrial volcanic structures strongly suggests that the area has been subjected to intensive and prolonged volcanic activities.

9. Descartes

The area of the southern highlands north of the crater Descartes is characterized by hilly, groovy, and furrowed deposits. It is bound on the west by a hilly and pitted stratigraphic unit and on the east by rugged hills which bound Mare Nectaris. The Descartes region, which is very similar to an area to the west and northwest of Mare Humorum, is thought to include a distinctive pattern of morphological manifestations of volcanism in the lunar terrae. Many of the elongate grooves and furrows are reminiscent of terrestrial volcanos. It is believed that a mission to a region of intensive and prolonged volcanism within the lunar terrae is most important, from both the geological and geochemical viewpoints. An alternative to this site would be that of Abulfeda.

10. Rima Prinz I

The Harbinger Mountains region of the moon includes numerous sinuous rilles and associated materials. The longest and, most probably, the youngest of the sinuous rilles in this area is Rima Prinz I. The latter is a double sinuous rille, i.e., a small meandering rille is enclosed within a larger sinuous rille. Sinuous rilles have aroused considerable interest because of the implications of the mode of their formation to the origin of the moon and its history. To study a sinuous rille, one must get down to the valley floor to sample the material and examine the displayed structures. Rima Prinz I was selected because of the freshness of its details. A landing near the mouth or terminus of the rille would allow an examination of the lower part of the eroded valley. The alternative to Rima Prinz I is Schroter's Valley which displays very similar characteristics, but appears older than Rima Prinz I.

The last three sites (Marius Hills, Descartes, and Rima Prinz I) include areas where mobility aids would be of the most service. It is assumed that a manned LRV would be developed for utilization in these three missions.

The coordinates of the landing points in the ten sites are given in Table I. These should serve as guidance points for trajectory studies, site analyses, geologic mapping, etc.

The Orbiter high resolution coverage of the ten sites is given in Table II. Photographic requirements should be considered at an early date to either obtain high resolution photographic coverage where needed, or select other sites if that is not possible.

Farouk El-Baz

2015-FEB-acm

F. El-Baz

Attachments
Figures 1 and 2
Tables I and II

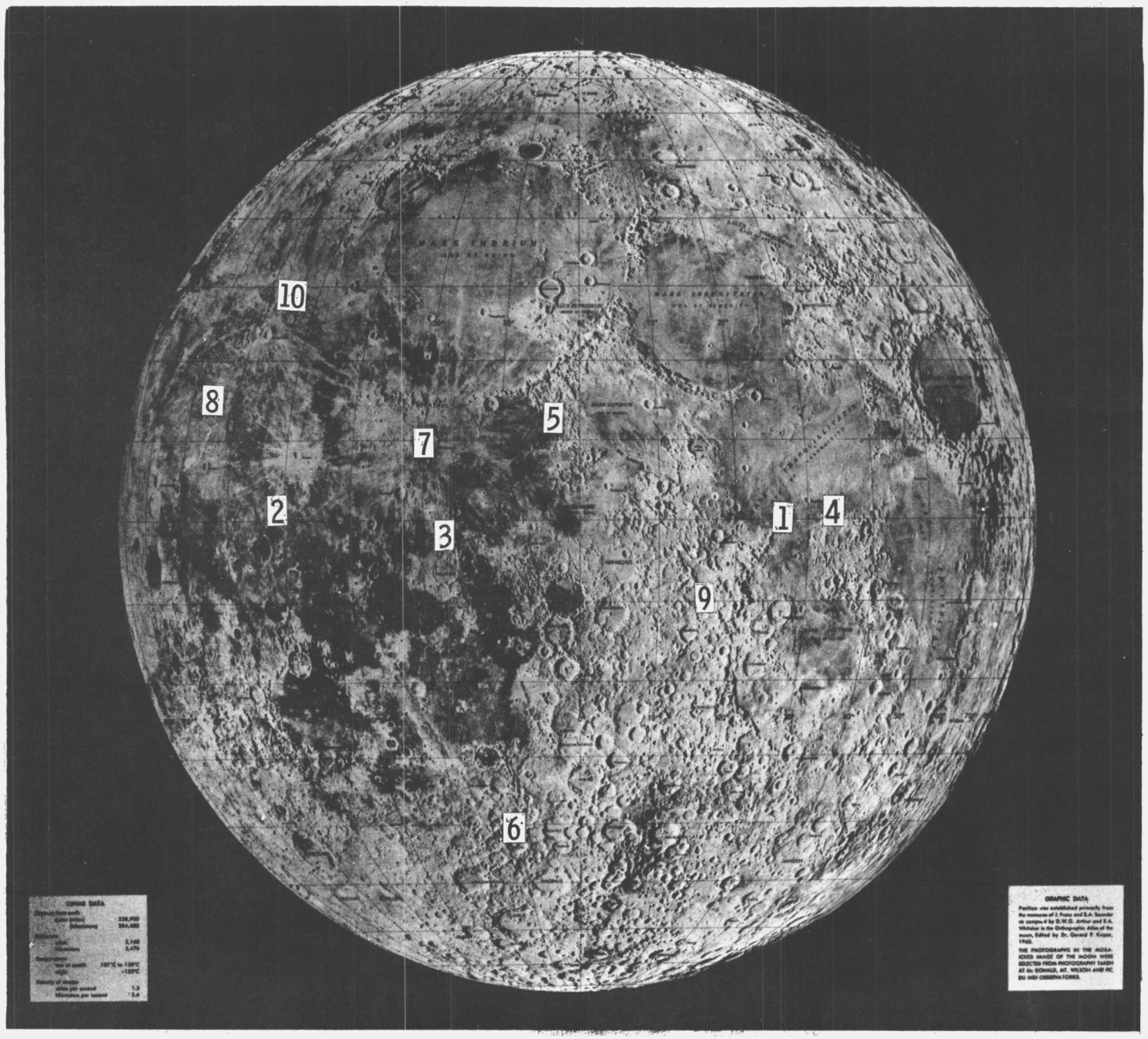

FIGURE 1

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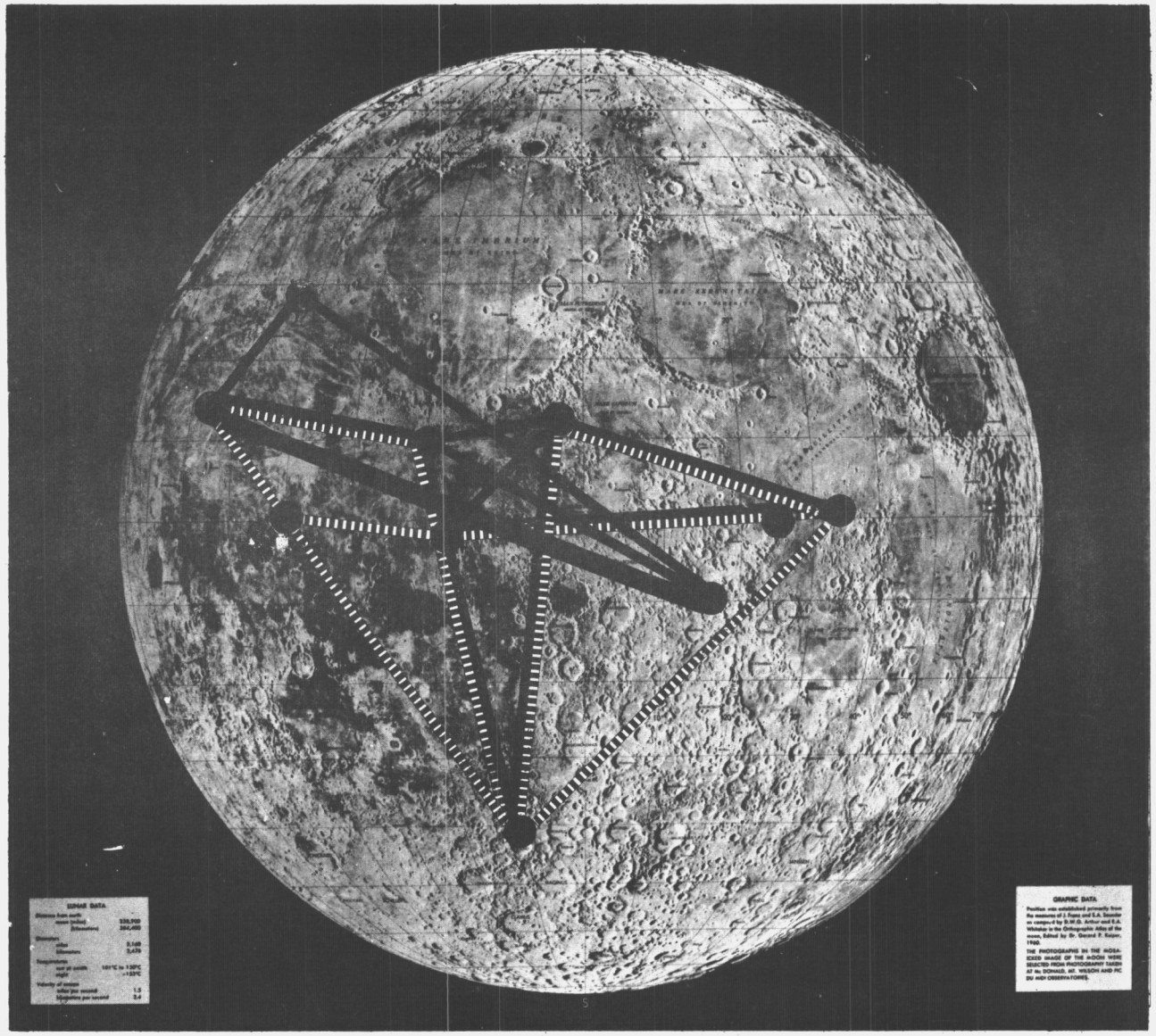
1. LANDING SITE 2
2. LANDING SITE 5
3. FRA MAURO FM.
4. CENSORINUS
5. RIMA BODE II
6. TYCHO (RIM)
7. COPERNICUS (PEAK)
8. MARIUS HILLS
9. DESCARTES
10. RIMA PRINZ I



MISSION ASSIGNMENTS
(BEST SEISMIC NETWORKS)

1. LANDING SITE 2
2. LANDING SITE 5
3. FRA MAURO FM.
4. CENSORINUS (NW)
5. RIMA BODE II
6. TYCHO (NORTH RIM)
7. COPERNICUS (PEAKS)
8. MARIUS HILLS
9. DESCARTES
10. RIMA PRINZ I

TABLE I

COORDINATES OF LANDING POINTS

	SITE	COORDINATES		SOURCE
1.	LANDING SITE 2	00^{0} 45' N	23^{0} 37' E	MSL TRIANGULATION
2.	LANDING SITE 5	01^{0} 41' N	41^{0} 54' W	MSL TRIANGULATION
3.	FRA MAURO FM.	03^{0} 44' S	17^{0} 30' W	LAC 76 2ND ED.
4.	CENSORINUS (NW)	00^{0} 20' S	35^{0} 00' E	PHOTOMAP (1969)
5.	RIMA BODE II	12^{0} 53' N	03^{0} 47' W	LAC 59 (1963)
6.	TYCHO (NORTH RIM)	40^{0} 56' S	11^{0} 15' W	LAC 112 (1967)
7.	COPERNICUS (PEAK)	09^{0} 42' N	20^{0} 18' W	LAC 58 (1964)
8.	MARIUS HILLS	14^{0} 36' N	56^{0} 34' W	LAC 56 (1963)
9.	DESCARTES	10^{0} 00' E	16^{0} 00' E	LAC 78 (1963)
10.	RIMA PRINZ I	28^{0} 06' N	44^{0} 22' W	LAC 39 (1963)

TABLE II

AVAILABLE ORBITER HIGH RESOLUSION PHOTOGRAPHY

	SITE	LO	SITE NO.	FRAMES	RESOLUTION IN METERS
1.	LANDING SITE 2	II	II P-6	76-91 (84)	1.05
2.	LANDING SITE 5	II	II P-13	197-212 (205)	1.00
3.	FRA MAURO FM.	III	III S-23	132-135 (133)	1.21
4.	CENSORINUS	V	V-12	63	2.41
5.	RIMA BODE II	V	V-29	120-123 (122)	2.30
6.	TYCHO (RIM)	V	V-30	125-128 (128)	4.70
7.	COPERNICUS (PEAK)	V	V-37	150-157 (152)	2.20
8.	MARIUS HILLS	V	V-51	210-216 (216)	2.40
9.	DESCARTES	IV	ORBIT 17	96	59.00
10.	RIMA PRINZ I	V	V-46	186-193 (193)	3.00

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